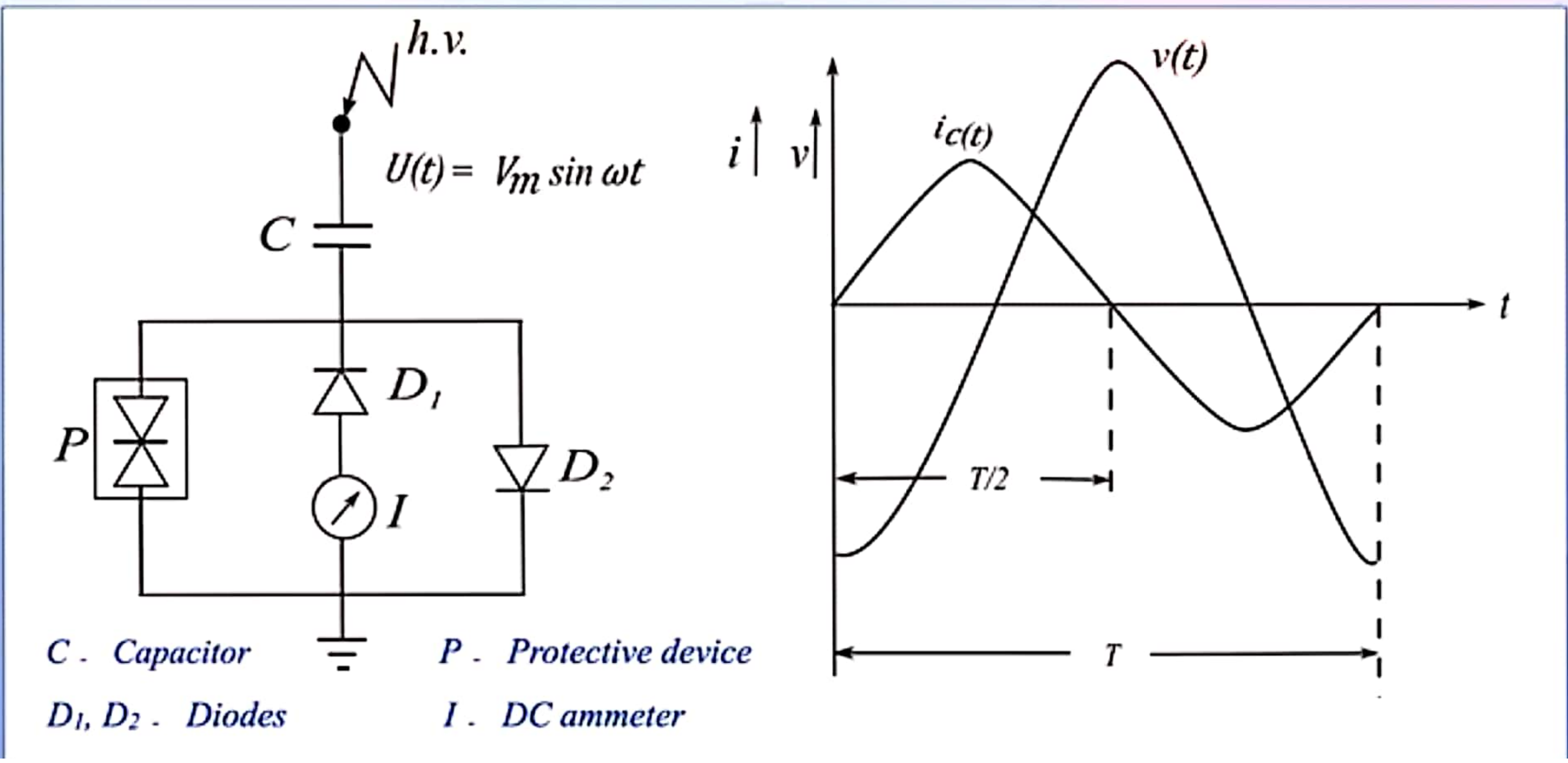
Topic 6: Measurement of peak value of AC voltages using (1) Series capacitor peak reading voltmeter

Series capacitor peak voltmeter
(Chubb- Fortescue method)



Principle :

1. When a capacitor charges through sinusoidal voltage, the charging current is given as $i_c = C\frac{dv}{dt}$

2. If charging current is limited to only one half cycle, then the arithmetic mean of charging current will be proportional to peak value of sinusoidal voltage.

   The DC ammeter reads current as , $I = \frac{1}{T}\int_{t_1}^{t_2} C\frac{dv}{dt}\,.\,dt$

   $$= \frac{C}{T} 2\, V_m$$

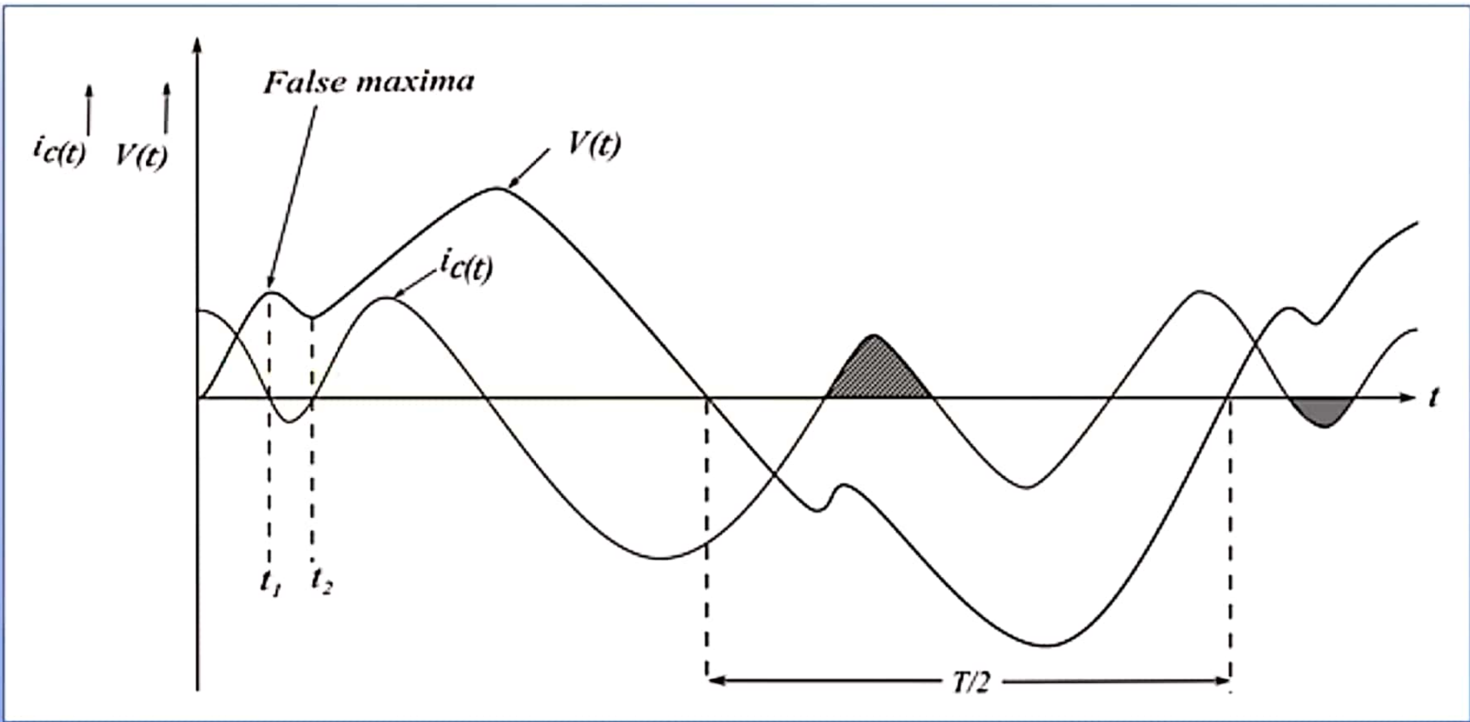
   $$I = 2fC\,V_m$$

3. The peak value of voltage, $V_m = \frac{I}{2fC}$

Circuit operation :

1. Maximum dielectric strength of insulators depends on the peak values of AC voltages. Determination of peak value of AC voltages based on r.m.s value will give error if waveform is non-sinusoidal.
2. When capacitor charges through the half wave sinusoidal voltage, the arithmetic mean of charging current is proportional to the peak value of A.C. voltage. This method is known as Chubb-Fortescue method.
3. The diode D_1 is used to rectify the capacitor charging current during negative half cycle of voltage, and diode D_2 bypasses the positive half cycle.
4. This method can be applied to A.C. voltages having balance and sinusoidal voltage waveforms in either half cycle. In case of presence of harmonics or multiple peaks, this method will fail.

Multiple peaks voltage waveforms



Error in measurement due to multiple peaks :

1. Due to multiple peaks in voltage, the charging current changes polarity within one half cycle itself.
2. The shaded area indicates reverse current during negative half cycle, hence this current will be subtracted from the net current. Thus the voltage peak value indicated would be lesser than actual.
3. Additional source of error is voltage drop due to pre-discharge current in the circuit. This can be taken care by using resistance in series with capacitor such that the discharge time-constant is very small as compared to the time period of A.C. voltage.
4. The error due to resistance will be

$$\frac{\Delta V}{V} = \frac{V - V_m}{V} = \left(1 - \frac{1}{1 + \omega^2 C^2 R^2}\right)$$

Sources of error in measurement :

1. Effective value of capacitor is different from the rated value of C.

2. Reverse leakage current in rectifier.

3. Multiple peaks in the non-sinusoidal waveforms.

4. Variation in the supply frequency.

Summary :

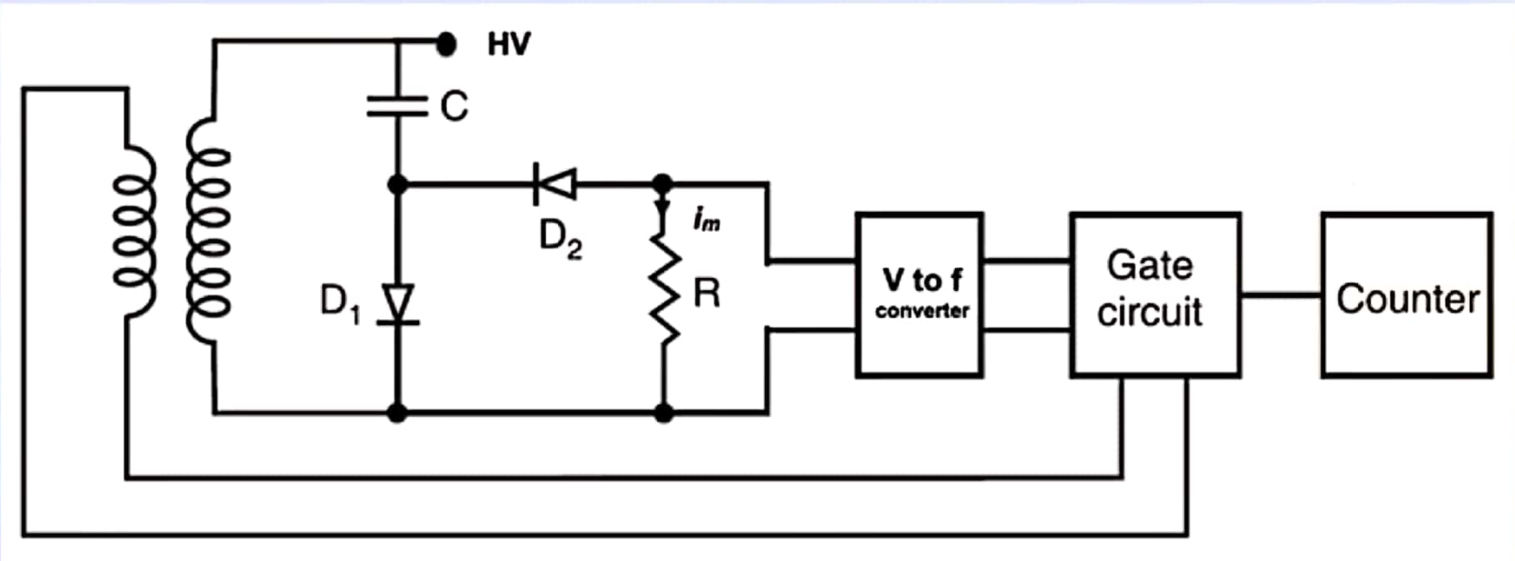
1. Series capacitor peak voltmeter works on the principle of measuring the arithmetic mean of rectified current.
2. The current is obtained through half cycle charging of series capacitance from the unknown A.C. voltage.
3. The non-sinusoidal voltage may have multiple peaks causing error in measurement.
4. Other sources of error are mainly deviation in capacitance, frequency and voltage drop due to the pre-discharge current.

Topic 7: Measurement of peak value of AC voltages

(2) Digital peak voltmeter

(3) Peak voltmeter with potential divider

Digital peak voltmeter



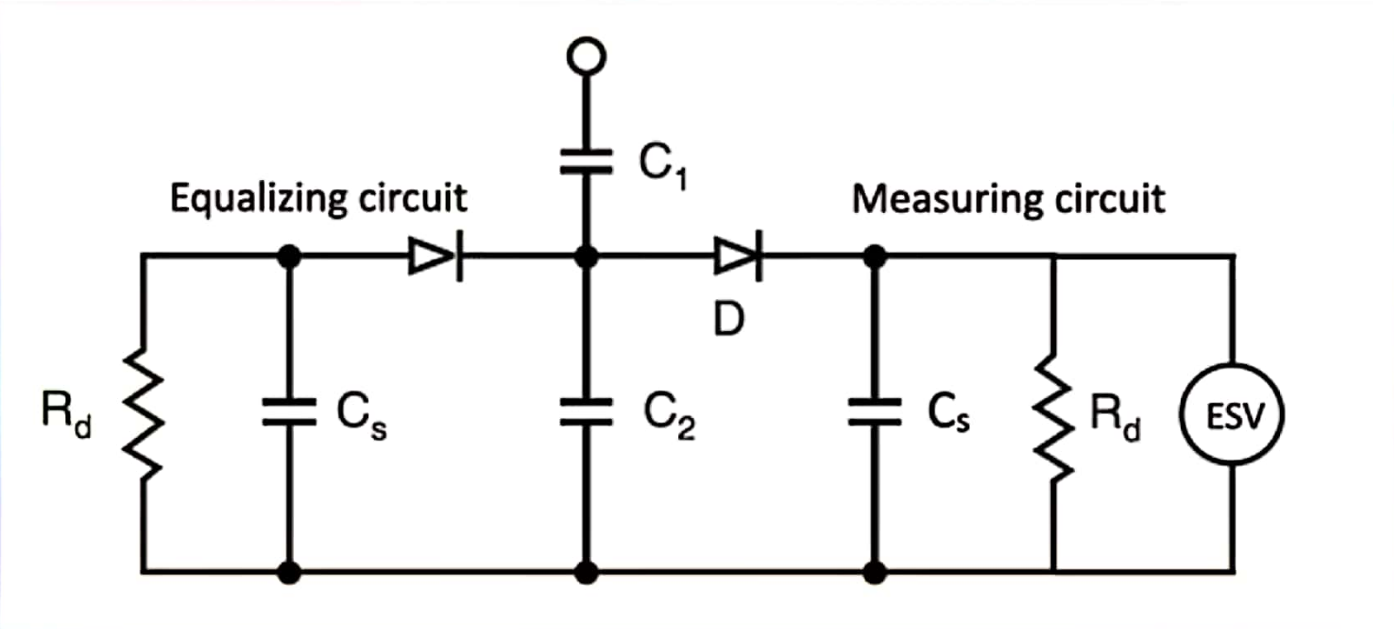
Circuit operation of Digital peak voltmeter :

1. The problem of multiple peaks in voltage waveform produces error.
2. A digital peak voltmeter does not rely on purely the rectified charging current. An analog voltage derived from charging current is converted into proportional medium frequency (f_m).
3. The ratio of frequency (f_m/f) is measured by the gate circuit controlled by the A.C. power frequency, and a counter is enabled for an adjustable period $\Delta t = \frac{p}{f}$ where 'p' represents constant of the instrument.
4. During this period the number of pulse are counted as 'n'

   $$n = f_m \Delta t = p\frac{f_m}{f} = 2pCV_m AR$$

   and A is voltage to frequency conversion factor $\frac{f_m}{R \cdot i_m}$

Peak voltmeter with potential divider
(Modified by Haefeely, Rabus)



Circuit operation :

1. The peak reading capacitance voltmeter circuit can be subdivided into two main sections namely measuring circuit and equalizing circuit.
2. The capacitance C_s in the measuring circuit gets charged to the peak value of voltage across capacitor C_2. This voltage can be measured by a high impedance voltmeter or electrostatic voltmeter (ESV).
3. Due to high impedance voltmeter the capacitor will hold the charge for duration of more than one second. As supply voltage reduces away from peak, the diode D will be reverse biased.
4. But due to this isolation of capacitor C_s, it no longer follows the supply voltage across the capacitor C_2. Hence discharge resistance R_d is connected to overcome this problem such that R_dC_s is approximately equal to 1 sec.

Circuit operation :

5. Due to the use of discharge resistance R_d , there will be discharge error produced as capacitors C_s and C_2 will keep discharging even if the input voltage is constant.
6. The second error is due to the ripple content of the voltage across the storage capacitor C_s, which depends on the supply frequency.
7. The third error is recharge error when diode is forward biased, the storage capacitor must be charged to peak value, but due to discharge resistance some drop in voltage occurs. This problem can be addressed by using high biasing resistor across capacitor C_2 and also keeping value of capacitance C_s less than capacitance C_2.
8. A modification in the method that minimizes these errors is use of equalizing circuit shown on the left side of measuring branch.

Summary :

1. Digital peak voltmeter works on the principle of converting the rectified AC charging current into a frequency, then enabling a counter using gate circuit. The gate circuit is synchronized with power supply frequency.
2. The digital measurements are costlier and require electromagnetic compatibility with strong electric field.
3. Capacitance potential divider based peak reading voltmeter uses storage capacitor to measure peak AC voltage, however the charging and discharging error needs additional modification.